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# MILITARY INTELLIGENCE DIVISION W. D. G. S.

## MILITARY ATTACHE REPORT G.B.
(Country reported on)

Subject MEASUREMENT OF RATES OF BURNING OF GERMAN PROPELLANTS & BRITISH S.U. PROPELLANTS (Brief descriptive title) I. G. No. 0404.0200

From M. A. London Report No. R5574-45 Date 24 October 1945.

Source and degree of reliability:

Projectile Development Establishment Report No. 1945/17. A-1.

SUMMARY.—Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.

BRITISH SUMMARY: "The German propellants considered were from the 21 cm. Wurfgranate Spr., the 28 cm. Wurfkorper and the 1800 kg. rocket assisted bomb. In the first place the rates of burning were obtained as comparative values using a sample of British S.U. cordite (Batch R.N. 1937.S.) as a standard. Later the absolute rate of burning of the standard was measured and thus the absolute rates of burning of the German propellants were calculated. The range of pressure considered was from 400 to 2,000 lb./sq.in. A few results have been obtained in the region of 3,000 lb./sq.in. and these are included in the report. The method used in the experiments from 400 to 2,000 lb./sq.in. was based on the interrupted burning technique described in P.D.E. report No. 1942/44. Standard 3 in. rocket tubes cut to various lengths and in some cases fitted with special chokes instead of venturis were used and by varying the conditions it was possible to obtain substantially rectangular pressure curves over the required pressure range. The German propellants gave comparative rates of burning ranging between the two extremes of 0.47 and 0.85 with respect to S.U. Cordite."

This will be of interest to the Ammunition Development Division Rocket Development Division, Ballistic Research Laboratory, Technical Service of Picatinny Arsenal and ORD CIT.

NOV 1 45 PM

1 Incl. as above,

Frank F. Reed
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Approved and forwarded.

For the Military Attache:

H. M. STOUT,
Lt. Col., GSC
Executive Officer.

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P.D.E. Report No. 1945/17

# The measurement of the rates of burning at zero gas velocity of some German propellants and of a British S.U. propellant

By J.D. Huffington and J. Iball.

Communicated by C.S.P.D.E.

March, 1945. P.D.E. Aberporth

Contents



## 1. Summary

The German propellants considered were from the 21 cm. Wurfgranate Spr., the 28 cm. Wurfkörper and the 1800 kg. rocket assisted bomb. In the first place the rates of burning were obtained as comparative values using a sample of British S.U. cordite (Batch R.N.1937.S.) as a standard. Later the absolute rate of burning of the standard was measured and thus the absolute rates of burning of the German propellants were calculated. The range of pressure considered was from 400 to 2,000 lb./sq.in. A few results have been obtained in the region of 3,000 lb./sq.in. and these are included in the report. The method used in the experiments from 400 to 2,000 lb./sq.in. was based on the interrupted burning technique described in P.D.E. report No. 1942/44. Standard 3 in. rocket tubes cut to various lengths and in some cases fitted with special chokes instead of venturis were used and by varying the conditions it was possible to obtain substantially rectangular pressure curves over the required pressure range. The German propellants gave comparative rates of burning ranging between the two extremes of 0.47 and 0.85 with respect to S.U. Cordite.

## 2. Introduction

The rate of burning of a propellant and the variation with pressure, temperature and with the velocity of gas over the surface is of obvious importance in the design of rockets. The Germans appear to have taken considerable trouble over the design of their rockets and it is of interest to examine the propellants which they have used and especially to determine their rates of burning.

Many methods of measuring rates of burning have been used by different investigators. It is desirable to burn the samples under conditions which give a steady pressure during the burning but this is not easy to achieve in practice. S.F. Boys[1] has used a technique which involves the burning of samples in a vented vessel and the interruption of the burning so that the partly burned samples are recovered and measured. A main charge is placed in the vented vessel to give the desired pressure and the end of the vessel is opened before the samples are completely burned through. The interruption of burning is achieved by supporting the venturi on a celluloid disc which is drilled with holes to a specified depth. The size and depth of the holes define the time at which the disc ruptures. When this happens the contents of the vessel are ejected and the samples recovered. Shackleton (see ref. 2.) used a method in which the propellant under investigation was allowed to burn completely in a vented vessel and the rate of burning was obtained by dividing the original thickness of the propellant by the time of burning, corrections being applied for the portion of the time during which the pressure was not constant.

Another method is that of Pike and Green[3] who used a closed vessel in which the pressure is raised rapidly to the desired value by means of a "booster" charge of thin cordite. The burning surface of the specimens is adjusted to compensate for the pressure fall due to cooling thus obtaining a flat-topped pressure curve. The completion of burning is indicated by a sudden change in the slope of the pressure curve.

The direct measurement of rates of burning by an electric timing method has been described by F. Daniels and collaborators[4] (University of Wisconsin). In these experiments and in those of Crawford, Huggett and Mc Brady[5] the time necessary to burn a long strand of the propellant was observed. The three last mentioned workers used a photographic method less convenient than the electric method but allowing an examination of the flame and providing a direct check on the regularity of burning. Henri Muraour[7] describes a somewhat similar method in which the timing is done by visual observation through thick glass, using a stop-watch.

The method used in the present investigation resembles that of Boys but uses a different method of interrupting the burning and instead of a large, heavy vented vessel standard rocket tubes suitably cut to length etc. are employed.

Only small quantities of the German propellants were available so that small samples had to be used. The detailed arrangements are described in the next section. The method of interruption is that described in P.D.E. Report No. 1942/4. It consists essentially of a device for separating, at a predetermined time, the rocket tube from the shell ring. The tube is blown off and the samples drop into a bath of water. The technique is one which has been in constant use for several years and rocket tubes are easily available so that our method has many advantages from the point of view of convenience. The interruption technique also gives a very good control over the time of burning. Using rocket tubes means that we are able to arrange a large number of firings to be done in quick succession and we avoid the delay involved in cleaning and preparing a large vented vessel. The method is also very flexible as one can vary the length of tube, size of choke, amount of charge etc. It is not however a very convenient method for pressures above 2,000 lb./sq.in.

## 3. Comparative rates of burning of German propellants.

The experimental arrangements used may be divided into three types according to the range of pressures required.

### 3.1. Type (a) experimental arrangement

This is for low pressures of about 400 lb. per sq.in. Diagram (1) shows the arrangement with the accessories for interrupting burning. An unseated 3" tube 34.5" long with a standard 1.45" diameter venturi was used. The charge was 16" of S.U.K. 3" cogged charge. The samples were cemented to a dummy cordite cruciform platform located at the shell ring end of the tube but not attached to the main charge. Usually four samples were used in each round, their dimensions being approximately ⅜" x ¼" x 2". One face (⅜" x ¼") was attached to the cruciform platform with the cement usually used for tabbing charges in rockets and the other end of the sample was covered by cementing to it a small dummy cordite end-piece (¼" x ⅜"). The two mutually perpendicular distances between the middles of the four exposed faces were measured by means of a screw micrometer. From these values before and after burning the rate of burning in inches per second could be calculated for each of the two directions at right angles. Usually the rate of burning was the same for these two directions, within the limits of experimental error. The reason for using an S.U.K. cogged charge is that the lowest working pressures under 3" rocket conditions appear to be obtained with this charge. A standard 2" rocket igniter strapped inside a cardboard collar was used and any remaining free space was occupied by cardboard collars to prevent the charge and samples moving about in the tube during transport. A number of rounds like this could be prepared and fired giving rapid information once the technique was established from preliminary firings.

The time before interruption of burning was usually about 0.5 sec., the time of burning before the pressure started to fall being about 0.7 sec. In 0.5 sec. the thickness of the sample is reduced by a little more than 30 per cent. A greater reduction in thickness would be desirable, but is impossible due to the limiting factor of the thickness of the cogged charge.

### 3.2. Type (b) experimental arrangement

For pressures from about 700 lb./sq.in. to 2000 lb./sq.in. 3" uncoated tubes cut to various lengths and with 0.5" diameter chokes were used. The charges used in this case were of tubular S.U. cordite 2.71 - 0.75" varying in length from 14" to 20.5". The samples were usually five in number (dimensions ½" x ½" x 2") cemented to the shell ring end of the charge. The arrangement is shown in diagram (2). The time before interruption of burning varied from 0.6 sec. to 0.35 sec. as the pressure varied from 900 to 2000 lb. per sq. in. In this case the samples tend to burn away before the charge, so that the reduction in thickness of the samples could be increased to about 70 per cent. before interrupting the burning. This improves the percentage accuracy in measuring the amount burnt away.

In early rounds the samples were attached to a separate cruciform platform as in the type (a) arrangement. It was found however, that they were frequently broken by this method, especially at the higher working pressures. It was thought that this was due to blast as the tube was parted from the shell ring when interruption took place. The samples were often found in a damaged condition on the floor of the firing chamber. In the new system the samples were cemented to the shell ring end of the charge. Normally the igniter would be placed in castellations at the shell-ring end of the charge, but the above arrangement makes ignition from the shell ring end difficult, and possibly damages the samples. Nozzle ignition was therefore employed as shown in Diagram (2). Occasionally ignition delays were encountered with nozzle igniters (consisting of S.R.371.C. 9 gm. loose and 7 gm. of pellets). This difficulty appeared to be overcome by using a 2" igniter inside the inner conduit just in front of the nozzle igniter.

Attempts were made to interrupt the burning at pressures above 2000 lb. per sq.in. but these were not very successful. It was found that the four shell ring studs, used in the interrupted burning head, tended to tear through the steel tube at pressures slightly above 2000 lb. per sq.in. A solution of this difficulty would be to use thicker tubes.

A satisfactory feature of the arrangements of Type (a) and Type (b) is that the pressure-time records are reasonably rectangular in shape. A typical pressure record obtained with arrangements of Type (a) is shown in Graph 1 and of Type (b) in Graph 2.

### 3.3 Type (c) experimental arrangement

Some results in the region of 3000 lb. per sq. in. were obtained by the celluloid disc closed vessel technique of Boys (Armaments Research Department).* The method of interruption is similar to that for vented vessels mentioned in the introduction. The initial rise in pressure was produced by igniting a quantity of 0.048" diameter S.C. cord. Since the vessel was completely closed a flat topped pressure record could only be obtained as a result of a falling pressure due to heat losses balancing a rising pressure due to burning of the samples. In our experiments with a minimum of two samples the pressure was steadily but slowly rising during burning.

* Details of this method have not yet been published.

at higher pressures it is easier to obtain a flat top to the pressure record as the extra pressure due to the burning of the samples becomes relatively less important. The initial pressure rise was too slow to allow us to ignore the burning taking place at low pressures, especially as the overall time of burning was quite small. This makes a special analysis necessary and this is described in the next section.

### 3.4. Details of calculation for accurate comparative rate of burning.

An approximate value for the comparative rate of burning can be obtained by comparing directly the distance burned off the specimen in unit time with that burned off the sample of S.U. cordite used as a standard. If the pressure curve is rectangular in shape then the pressure at which this rate of burning applies is then known accurately. However in practice the pressure curves are not exactly rectangular and some assumption or correction must be used in order to specify the pressure and the corresponding comparative rate of burning. In our experiments the pressure records were very nearly rectangular and in any case over the main portion of the burning time the curve was a straight line. It was thought therefore that the pressure at "half-burnt" would give a sufficiently accurate measure of the effective pressure at which the observed rate of burning was applicable. The following analysis shows that in the case of results obtained with arrangements of types (a) and (b) when the appropriate corrections are calculated both for the rate of burning and for the pressure the corrected results are not significantly different from the uncorrected results obtained directly as above. The correction involved is small so that the approximate comparative rates of burning may be used in calculating the correction without much error. It is also safe to assume that Shackleton's[2] results for the absolute rate of burning of S.U. cordite may be used in obtaining the correction.

To calculate* the correction we assume that we know (a) the rate of burning of S.U. as a function ($S(p)$) of pressure, and (b) the comparative rate of burning of the particular propellant as a function ($R(p)$) of pressure. Then $R(p)\,S(p)$ is the absolute rate of burning of the particular propellant. Let the suffixes o and f refer to the beginning of the pressure rise and the end of the pressure curve at interruption. Choose a point c dividing the pressure curve into the rising portion, for which the correction is to be applied, and the portion over which the pressure is approximately constant. Let $\eta$ be the ratio of the amounts burnt off the samples, when we have

$$(1) \quad \eta = \frac{\int_o^c R(p)\,S(p)\,dt + \int_c^f R(p)\,S(p)\,dt}{\int_o^c S(p)\,dt + \int_c^f S(p)\,dt}$$

* See reference (1) from which this argument is derived

Since $p$ and $\overline{R}$ are nearly constant in the range e to f, we can define a mean value of R by

$$\overline{R} = \frac{\int_e^f R(p)\, S(p)\, dt}{\int_e^f S(p)\, dt}.$$

and hence from equation ([illegible])

$$\overline{R} = \eta\left(1 + \frac{\int_o^e S(p)\, dt}{\int_e^f S(p)\, dt}\right) - \frac{\int_o^e R(p) S(p)\, dt}{\int_e^f S(p)\, dt}.$$

It will be noticed that both the correction terms have an integral o to e for numerator and hence will be small when the pressure rise is rapid. In addition an important point is that the correction does not depend on the absolute magnitude of the function S(p) assumed for the rate of burning of S.C. but only on its shape since, if S(p) were multiplied by any constant, the above corrections would be unaltered. The curve which was assumed for the function of S was based on the measurements made by Shackleton(2) which have been confirmed by Boys and Pike.

The value of $\overline{R}$ using the above relation was calculated for one of the cases most likely to need correction recorded with the Type (a) and (b) arrangement. In this particular case the ratio of the time taken to reach the steady pressure (o to e) to the total burning time (e to f) was 0.08[illegible]. The total burning time was 0.35 sec. The corrected value for the comparative rate of burning of the German propellant was 0.801. The approximate value obtained directly from the ratio of the amounts burned off the two samples was 0.799, representing a negligible difference.

The value of $\overline{R}$ calculated above was the mean comparative rate of burning in the range e to f. It remains to calculate the mean pressure in the range e to f corresponding to $\overline{R}$ the mean ratio in this range. There are various ways of calculating a mean value, none of which would be widely different, but the mean which corresponds accurately to $\overline{R}$ can be obtained as follows. The equations defining $\overline{R}$ and $\overline{S}$ are :

$$\overline{R} = \frac{\int_e^f R(p)\, S(p)\, dt}{\int_e^f S(p)\, dt}, \qquad \overline{S} = \frac{\int_e^f S(p)^2\, dt}{\int_e^f S(p)\, dt}.$$

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We assume that the pressure corresponding to $\bar{S}$ calculated from the above equation is also the pressure corresponding to $\bar{X}$. This will obviously be correct since the pressure is nearly constant from o to f and the rates of burning of S.U. and the propellant considered are similar functions of pressure. Hence, to obtain $\bar{p}$, we obtain $\bar{S}$ from the above equation and then read the value of $\bar{p}$ corresponding to this from the given S - p curve. In the case of the example quoted above the value of $\bar{p}$ was 1960 lb. per sq.in. compared with a pressure at half burnt of 1945 lb. per sq.in.

4. <u>Absolute rate of burning of HM.1937.S.</u>

To convert the comparative rates of burning of the German propellants to absolute rates it was necessary to determine the absolute rate of burning of the standard at various pressures. A separate series of experiments was carried out for this purpose.

4.1 <u>Experimental details</u>

Instead of the usual sample (¾" x ¾" x 2") a single tubular sample of HM.1937.S. (2.71" - 0.75") was used. This was made 3" long and cemented to the top of the main charge. The time before interrupting burning could then be increased, as the limiting factor of sample size no longer applies. Times of 1.2 sec. at 700 lb. per sq.in. to 0.7 sec. at 2000 lb. per sq.in. were used in this way. The arrangement is shown in Diagram 3. Before the sample was attached to the main charge its thickness was measured by means of a micrometer with one ball face, suitable for measurements on curved surfaces. A light and uniform pressure was obtained in all cases by tightening the micrometer to the extent of two clicks of the ratchet. The positions of measurement were at four points equidistant from each other round a circumference of the charge 0.8" from the joint with the main charge (i.e. 2.2" from the shell ring end of the sample). The sample was removed from the backing charge and measured at the same positions after burning. Any lack of symmetry in the rate of burning could be detected in this way, but a variation round the circumference was only found in one case. In this instance it was noticed that the higher rate of burning (0.314 in. per sec.) occurred on the same side of the charge as a breakdown of the cement joining the sample to the main charge. The disturbance of the gas flow caused by the hole so produced would probably account for the variation in the rate of burning. The rate of burning on the diametrically opposite side of the charge was 0.302 in. per sec. representing a maximum variation round the circumference of about 4 per cent.

It was found to be impossible to use tubular charges of S.U. at much below 400 lb. per sq.in. because of unstable burning. However cogged charges of S.U.K. could be used although the time of burning could not be increased beyond about 0.5 sec. on account of the relatively small thickness of cordite in the cogged charge.

As with comparative rates of burning corrections are necessary if the pressure curve departs from a rectangular shape. Pressure records at 700, 1300 and 2200 lb. per sq. in. are shown in Graphs 3, 4 and 5. It is to be expected that due to the relatively long times of burning in these records the correction due to the initial rising part of the pressure curve will be small enough to be neglected. This fact was established by means of the following analysis.

### 4.2. Details of calculation for accurate absolute rates of burning*

Let us denote by $B$ the rate of burning in ins. per sec. actually occurring in these experiments, while using $S$ as above for the function of $p$ thought to be the best rate of burning consistent with previous results. If $\Delta d$ represents the measured amount burnt off the S.U. sample we have

$$\Delta d = \int_0^c B\,dt + \int_c^f B\,dt$$

$$\text{or} \quad \Delta d\left(1 - \frac{\int_0^c B\,dt}{\int_0^f B\,dt}\right) = \int_c^f B\,dt.$$

The term $\dfrac{\int_0^c B\,dt}{\int_0^f B\,dt}$ is the small correction

term contributed by the finite time taken for the rise of pressure, and in this term we can replace $B$ by $S$. We define the mean value of $B/S$ which is a slowly varying function of $S$ by

$$\overline{B/S}\;\bar{S}\int_c^f S\,dt = \int_c^f \frac{B}{S}\,S\,dt = \int_c^f B\,dt.$$

and obtain the mean value of $S$ corresponding to this mean as in the above paragraph which is

$$\bar{S} = \frac{\int_c^f S^2\,dt}{\int_c^f S\,dt}.$$

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* See reference (1).

Hence the mean value of $B$ corresponding to $\bar{S}$ is given by

$$\bar{B} = \Delta d \frac{\int_c^f S^2\,dt}{\left(\int_c^f S\,dt\right)^2} \left(1 - \frac{\int_0^c S\,dt}{\int_0^f S\,dt}\right)$$

It will be noted that this is simply a more refined form of

$$\bar{B} = \frac{\Delta d}{t_f - t_0}$$

since

$$\frac{\left(\int_c^f S\,dt\right)^2}{\int_c^f S^2\,dt}.$$

is the effective time of burning from $c$ to $f$. We have obtained the relation between $B$ and $S$ and hence between $B$ and $p$, since the relationship between $S$ and $p$ is known from Shackleton's results.

Examination of the pressure records shows that corrections are likely to be greatest in the region of 2000 lb. per sq. ins. since it is here that the initial rise to a maximum pressure takes the greatest proportion of the total burning time. However at the low end of the pressure range, near 700 lb. per sq. in. - although the burning time is long the pressure tends to drop towards the end of burning, due probably to a reduction in the total burning surface. Since the tubular charges used were shorter at low pressures the effect of the reduced end surface areas as burning proceeds is more noticeable at low pressures than at high pressures. Corrected values for the rates of burning were therefore calculated, according to the above equation, for firings at 700 and 2000 lb. per sq. ins., with the following results :-

| | Uncorrected | Corrected |
|---|---|---|
| Pressure lb. per sq.in. :- | 695, 2190 | 680, 2210 |
| Rate of burning in. /sec. :- | 0.301, 0.559. | 0.302, 0.566 |

The uncorrected values in the above table were obtained directly by dividing the amount burnt off the cordite by the time of burning, the pressure being the pressure at half burnt. In graph 6 points obtained in this way are shown with the two corrected values at 700 and 2000 lb. per sq. in. showing that the correction can be ignored. The solid line represents the results of Pike and Green(3) corrected from 80°F. to 50°F. Pike and Green's experiments were carried out with S.C. at 80°F. whereas our samples were at approximately 50°F. when fired. In correcting Pike and Green's values a figure of 0.4 per cent. increase in the rate of burning for 1°C. rise in temperature was used.

5. Results and discussion

The samples of German and British propellants were cut from sticks normally used in rockets. Except in the case of the 1800 Kg. rocket assisted bomb no great difference in the results from different sticks was observed. Only two sticks of British R.N. 1937.B. were considered, two sticks of German "21 B", two sticks of "21 C", one stick from the 28 cm Wurfkörper and two sticks from the 1800 Kg. bomb. The propellant from the 21 cm. Wurfgranate Spr. was divided into two types, 21 B and 21C. It was thought originally that 21 B propellant was suitable for temperate climatic conditions and 21 C for tropical conditions. However, chemical analysis reveals little difference in composition between 21 B and 21 C, although the rates of burning of 21 B are slightly greater (6 per cent at 1200 lb. per sq. in.) than those of 21 C. as shown in Graphs 8 and 9.

Unusual results were obtained with the 1800 Kg. bomb propellant. Samples from stick 1 showed no difference between the rates of burning in two perpendicular directions of the same sample. Some samples from stick (4) however gave rates of burning differing by as much as 15 per cent. in the two perpendicular directions. Referring to Diagram (4) representing a cross-section of a charge and of a sample, the higher rate of burning is along A B and the lower rate along C D. Also the final cross-sectional shape of the sample is shown by the dotted line. It seems that layers of cordite nearer to the surface of the original charge burn faster. However, inconsistent results were obtained, even with samples cut from the same stick and fired in the same round under identical conditions. For instance four samples of 1800 Kg. bomb propellant (Stick 4) fired in the same round with a sample of R.N.1937.B. as standard gave the following comparative rates of burning :-

| | Direction A B | Direction C D |
|---|---|---|
| Sample 1 | 0.70 | 0.60 |
| Sample 2 | 0.68 | 0.60 |
| Sample 3 | 0.70 | 0.70 |
| Sample 4 | 0.69 | 0.64 |

The results for the 1800 Kg. bomb (Stick 4) are shown in graph 10 in which a distinction is made between the rates of burning in the directions A B and C D. The curves through these points can only be approximate on account of the irregularity of the results. Some results for Stick 1 are also shown in graph 10. The reason for surface layers of this propellant behaving differently from deeper layers is unknown, but it would probably be revealed by chemical analysis of the different layers. Crawford and Huggett (6) find a decrease of the burning rate with increased humidity for double base propellants, so that absorption of moisture by surface layers of the 1800 Kg. bomb propellant seems to be an unlikely explanation for the above results.

The results for the 28 cm. Wurfkörper propellant are shown in graph 7. The points seem to be quite consistent, and the curve is more linear than usual.

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The points shown in graph 6 refer to the rate of burning of RN.1937.S. at 50°F. The solid curve represents Pike's results for S.C. chosen for comparison. There is little difference between the results of Shackleton, Boys and Pike, the greatest divergence being between the results of Boys and Pike. In general Boys' results are about 4 per cent. greater than Pike's, the difference between our results and those of Boys except at low pressures where, for instance at 400 lb. per sq. in. Boys' results are 8 per cent. less than ours. It is to be noted that there are differences of the order of 5 per cent. between different manufactured lots of nominally the same propellant.

Some results for comparative rates of burning of German propellants in the region of 3000 lb. per sq. in. are given in the following table. These are only approximate as no corrections have been applied. Arrangements of Type (C) were used to obtain these results.

Temperature of samples when fired 60°F. approx.

| | Pressure | Comparative Rate of Burning |
|---|---|---|
| 21 B Wurfgranate Spr. | 3070 lb./sq.in. | .785 with respect to S.C. |
| " | 3276 " | .76 " |
| 21 C Wurfgranate Spr. | 2828 " | .78 " |
| | 3160 " | .76 " |


(1) The comparative rates of burning of five propellants at low pressures as determined by an interrupted burning technique. S.F. Boys. A.R.D. Ball. Report 74/42.

(2) This work was done in the R.D. in 1938; the results were discussed by D.R. Hartree, Theory of the internal ballistics of the U.P. A.C. 1027/IBA.

(3) An alternative method of measuring the rates of burning of propellants and its application to S.C. H.R.M. Pike and H. Green. A.R.D. Ball. Report 16/44.

(4) The mechanism of powder burning. F. Daniels and collaborators, N.D.R.C. Report A - 243 (O.S.R.D. No. 3206). Jan. 1944.

(5) Observations on the burning of double base powders. Crawford, Huggett and McBrady N.D.R.C. Report A - 268 (O.S.R.D. No. 3544), April, 1944. See also :-

(6) Direct measurement of burning rates by an electric timing method. Crawford and Huggett N.D.R.C. Report A - 286 (O.S.R.D. No. 4009) August, 1944.

(7) Note sur la vitesse de combustion des poudres colloïdales en fonction de la pression et de la temperature des gaz émis. Henri Muraour. Bulletin de la Societe chemique de France, Mars - Avril, 1942.




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DIAGRAM (1)

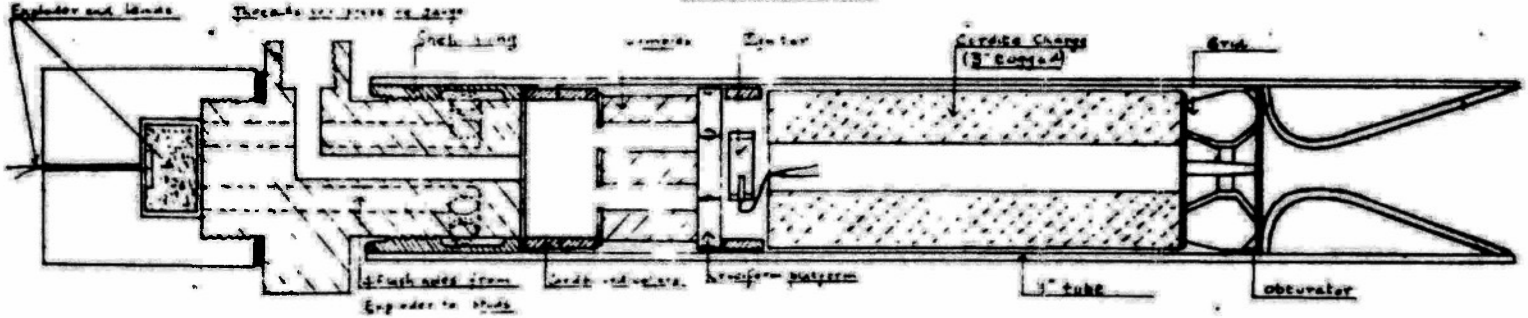



DIAGRAM (2)

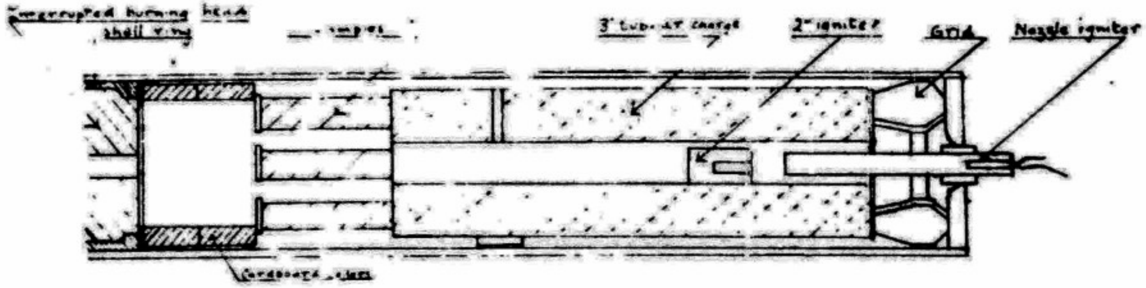
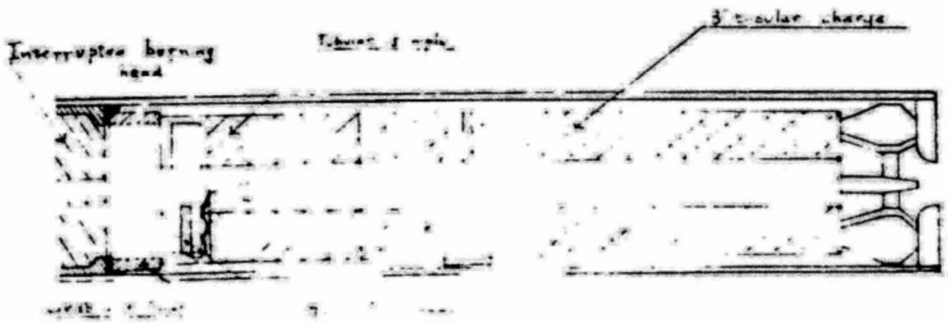
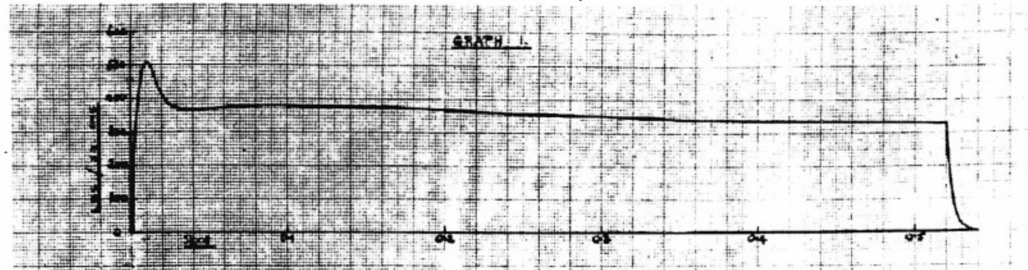


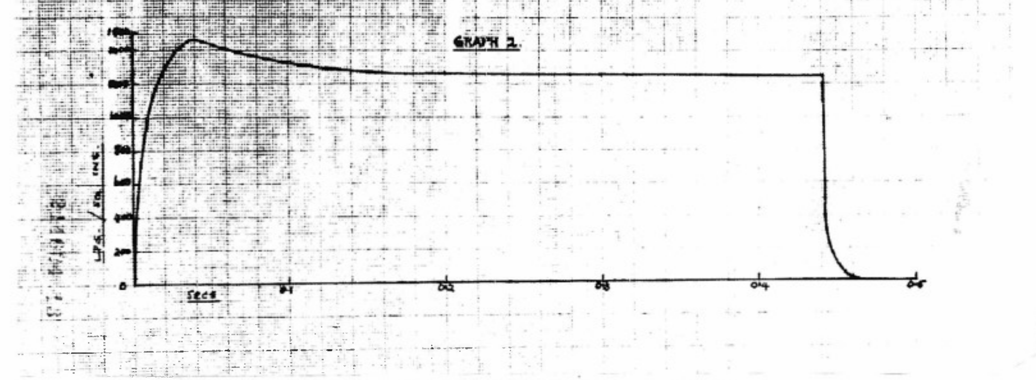

DIAGRAM (3)

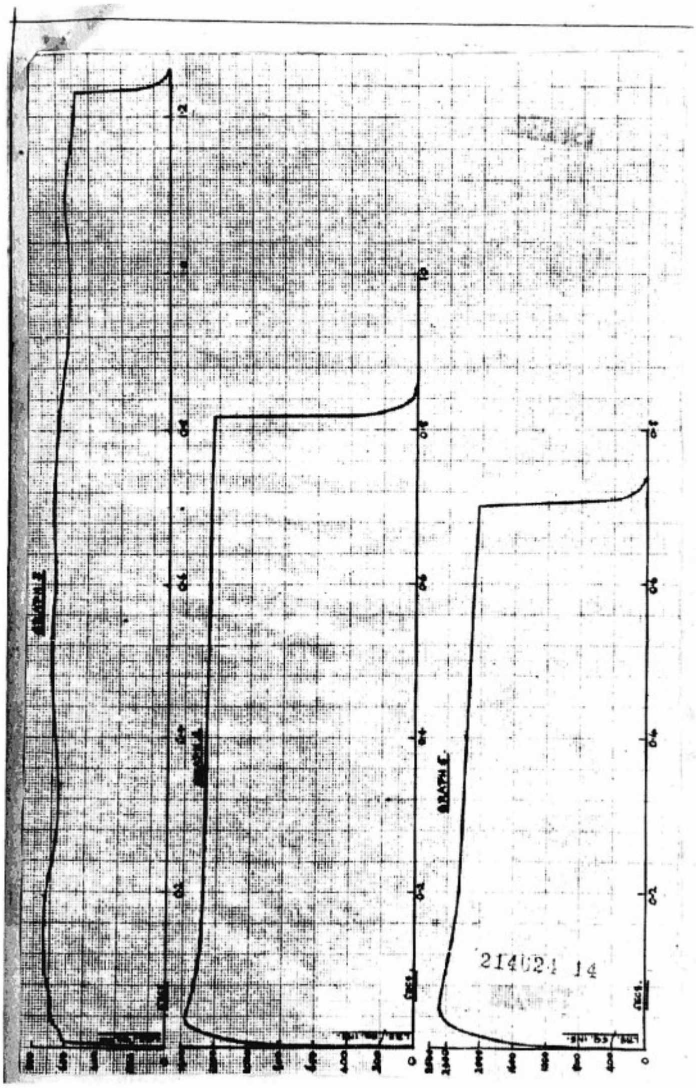


GRAPH 1.




GRAPH 2.

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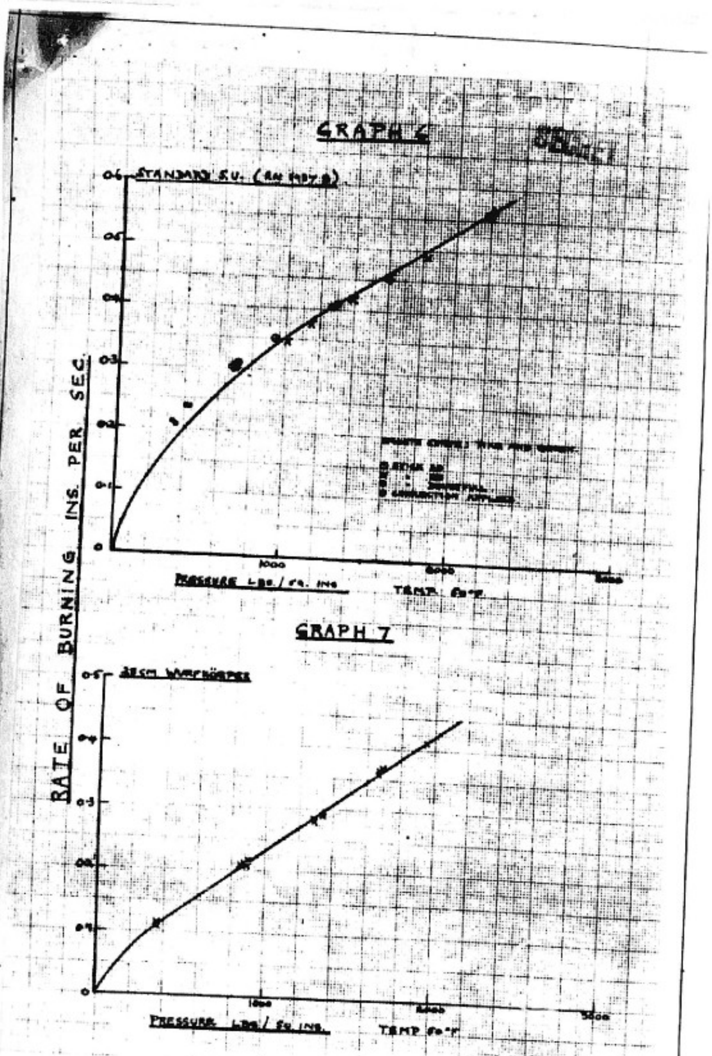
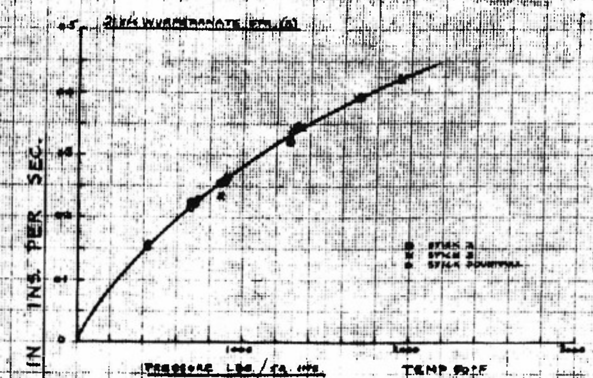


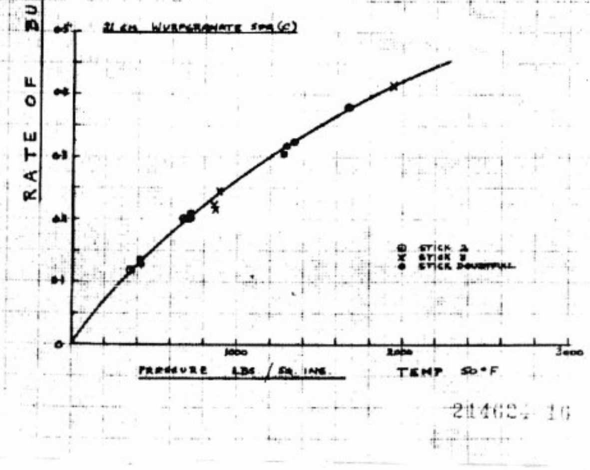
GRAPH 6
STANDARD S.U.
RATE OF BURNING INS. PER SEC.
0
0·1
0·2
0·3
0·4
0·5
0·6
1000
2000
3000
PRESSURE LBS./SQ. INS.
GRAPH 7
0
0·1
0·2
0·3
0·4
0·5
1000
2000
3000
PRESSURE LBS./SQ. INS.
TEMP.


214624 15.

## GRAPH 8

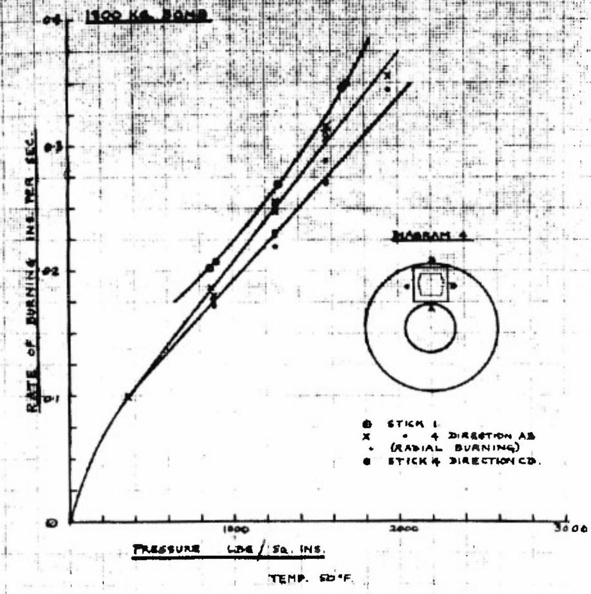



## GRAPH 9




214624 16

GRAPH 10

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FRAME

1467

SECRET

TITLE: The Measurement of the Rates of Burning at Zero Gas Velocity of Some German Propellants and of a British S.U. Propellant

AUTHOR(S) : Huffington, J.D.; Iball, J.

ORIG. AGENCY : Projectile Development Establishment, Ministry of Supply, Aberporth

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ABSTRACT:

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